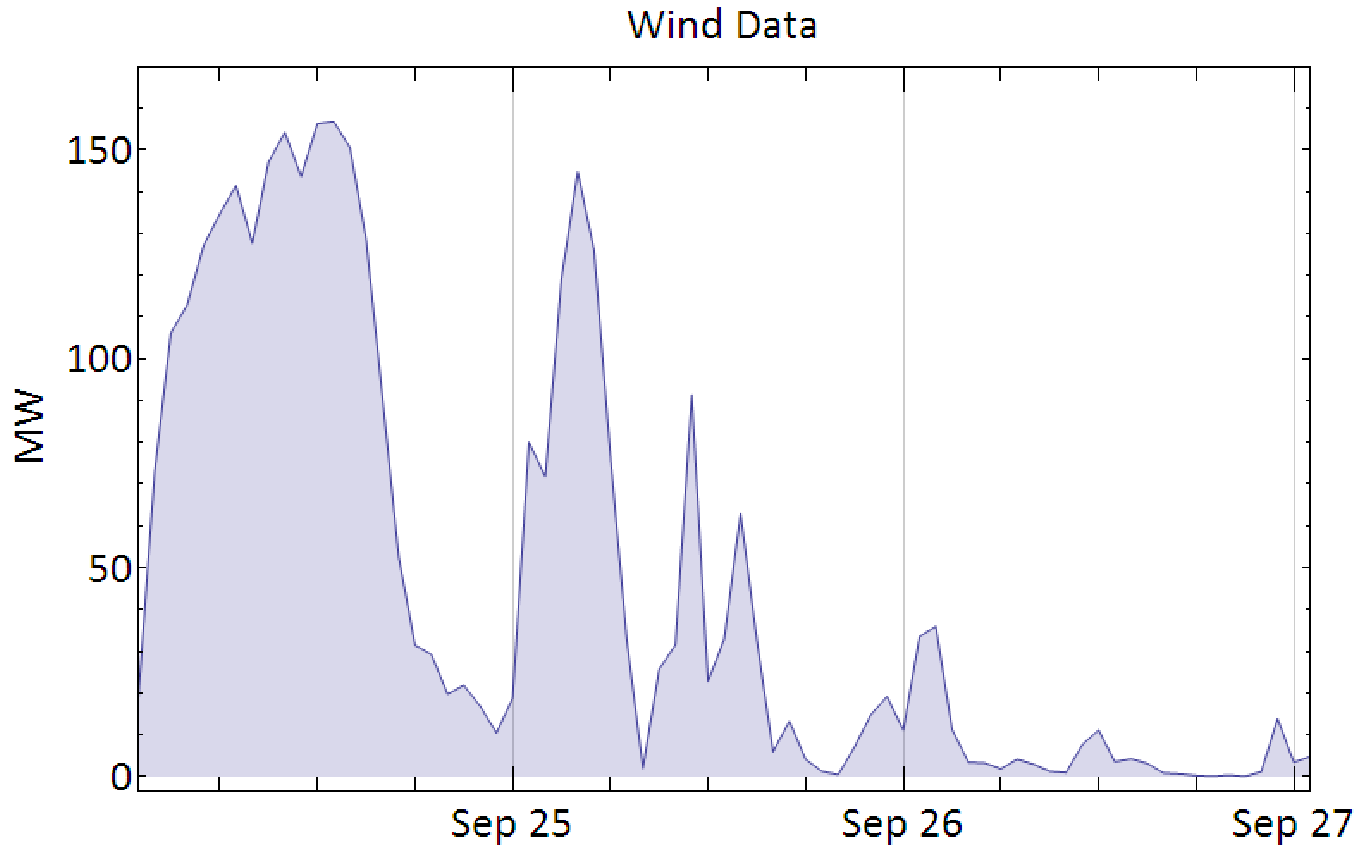
Emerging Ideas II

Renewable Energy Forecasting

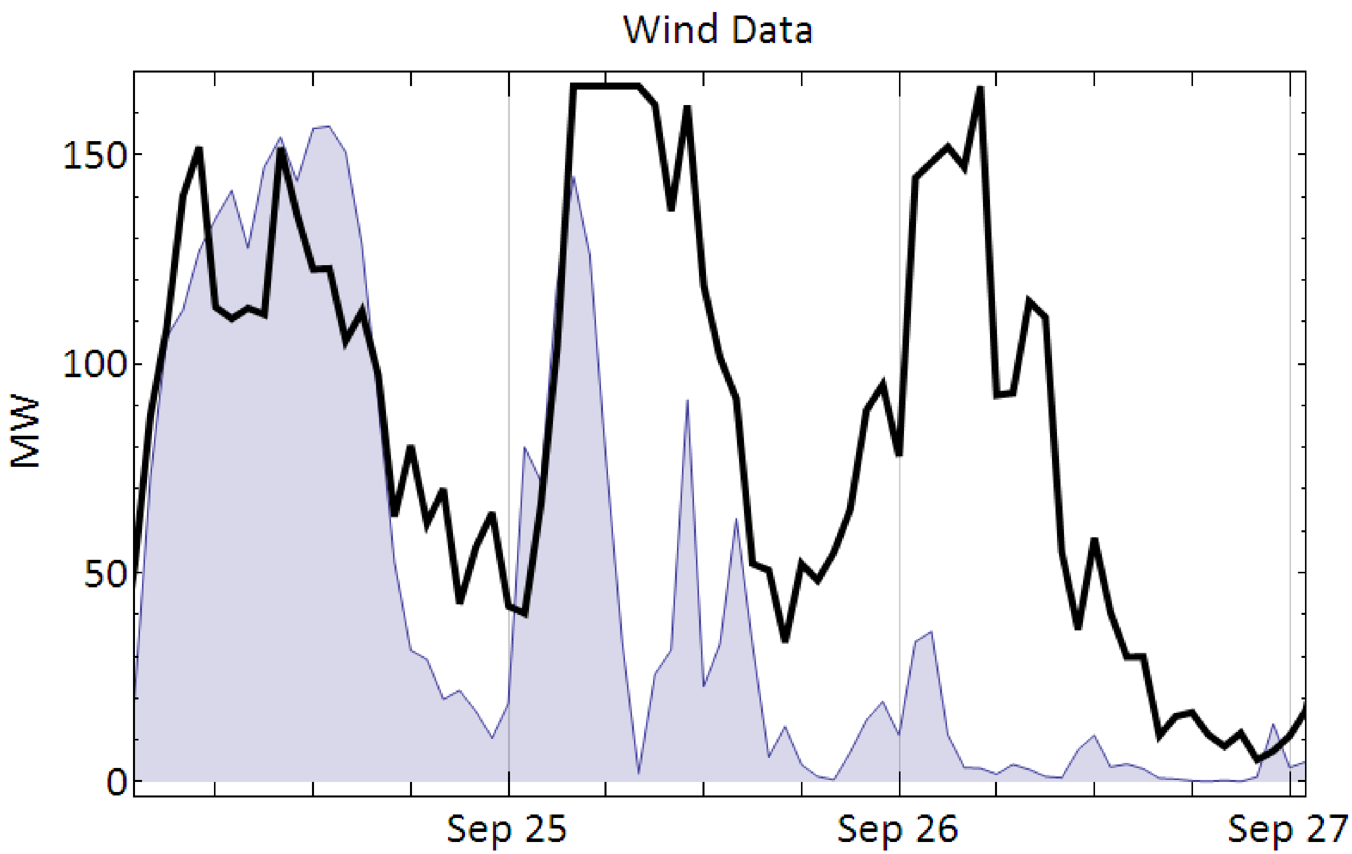
Phil Larochelle,
ORISE Postdoctoral Researcher
Contractor to ARPA-E

Wind is Variable



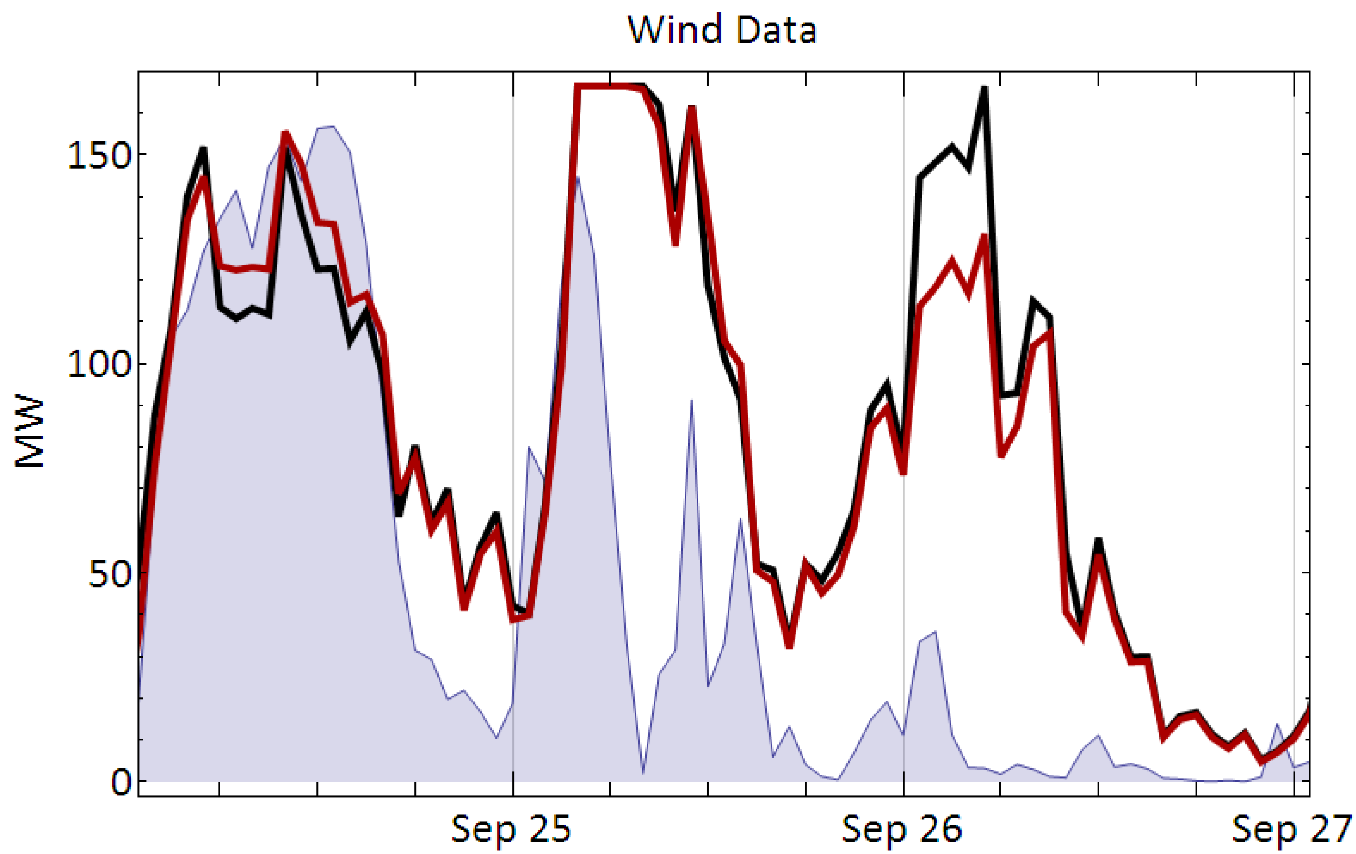
Actual
Wind
Production

Wind is Variable & Forecasts are Imperfect



Actual
Wind
Production
Day Ahead
Forecast

Wind is Variable & Forecasts are Imperfect



Actual Wind Production
Day Ahead Forecast
4 Hour Ahead Forecast

State of the Art Forecasting Technology Performance

Table 2

Average Wind Forecast Error by Time Frame

	Forecast Error	
	Single Plant	**Region**
Hour Ahead		
Energy (% Actual)	10 – 15%	6 – 11%
Capacity (% Rated)	4 – 6%	3 – 6%
Day Ahead		
Hourly Energy (% Actual)	25 – 30%	15 – 18%
Hourly Capacity (% Rated)	10 – 12%	6 – 8%

Source: Smith, 2009.

Bad Forecasting Results In:

- Requirement of additional balancing reserves
- Underproduction/ curtailment of wind and solar
- Contingencies and outages

The Value of Wind Power Forecasting

Preprint

Debra Lew and Michael Milligan
National Renewable Energy Laboratory

Gary Jordan and Richard Piwko
GE Energy

	10% Forecasting Improvement	20% Forecasting Improvement
14 % Wind Penetration	$140 M	$260 M
24% Wind Penetration	$500 M	$975 M

ISO-NE Data 2011/7/19, EIA 2009 Data

Techno-Economic Goal

Measurement and Data Analytics that Result in > 40% Improvement on State of the Art Forecasting Techniques for Wind and Solar Power

Technologies that Can Do It

Hardware: Improved Sensors (Accurate, Low-Cost and Remote)

Software: Data Aggregation, Analysis and Forecasting

Wind Sensing Techniques

RADAR

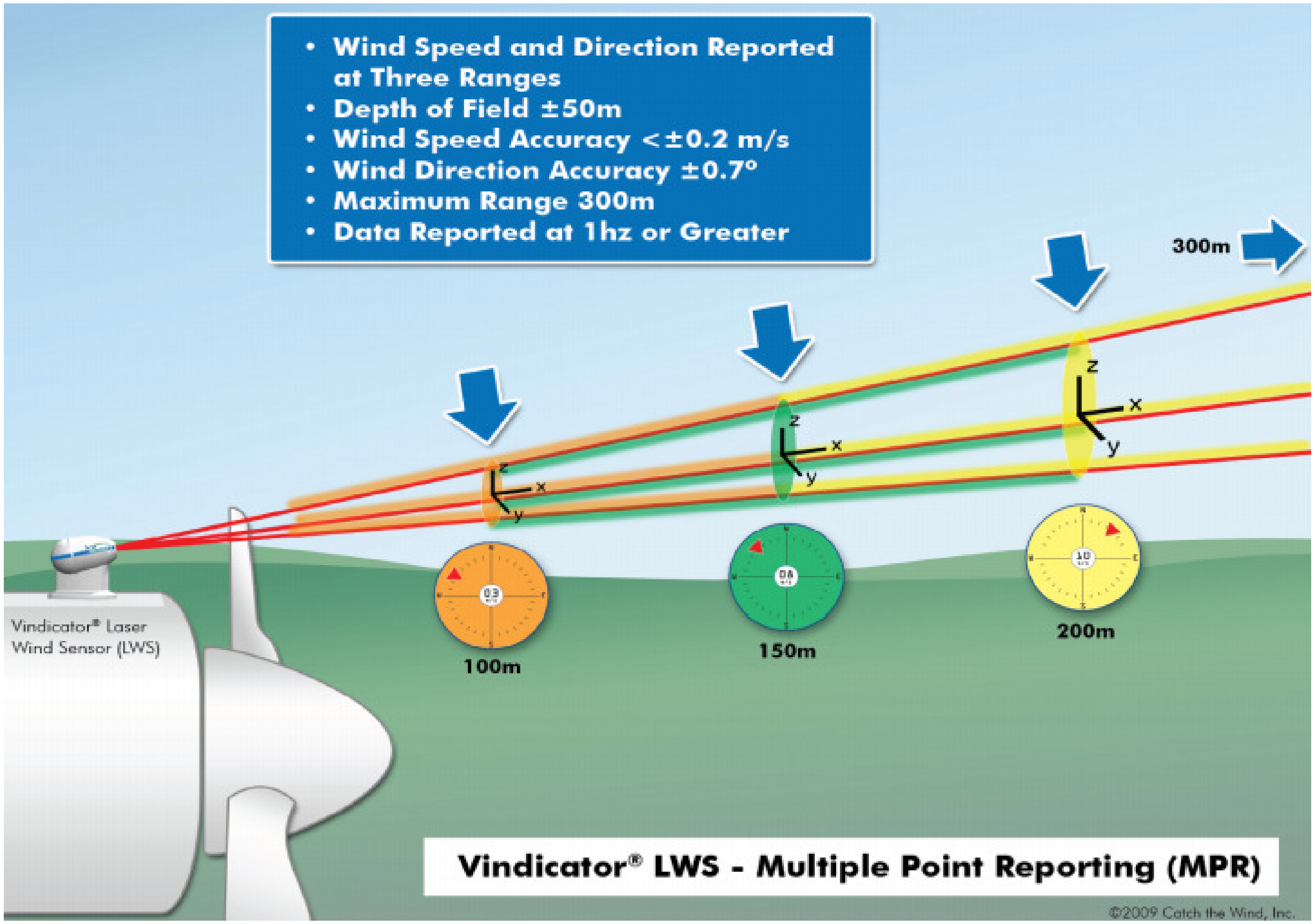
Anemometer

SODAR
(Sound Detection and Ranging)

LIDAR: Light Detection and Ranging
Look at the Doppler Shift of Back Scattered Light

State of the Art: Stationary Installations for the Characterization of Resources

Ranged LIDAR: Can we push this technology and make it ubiquitous? Can we extend the range > 1 km?



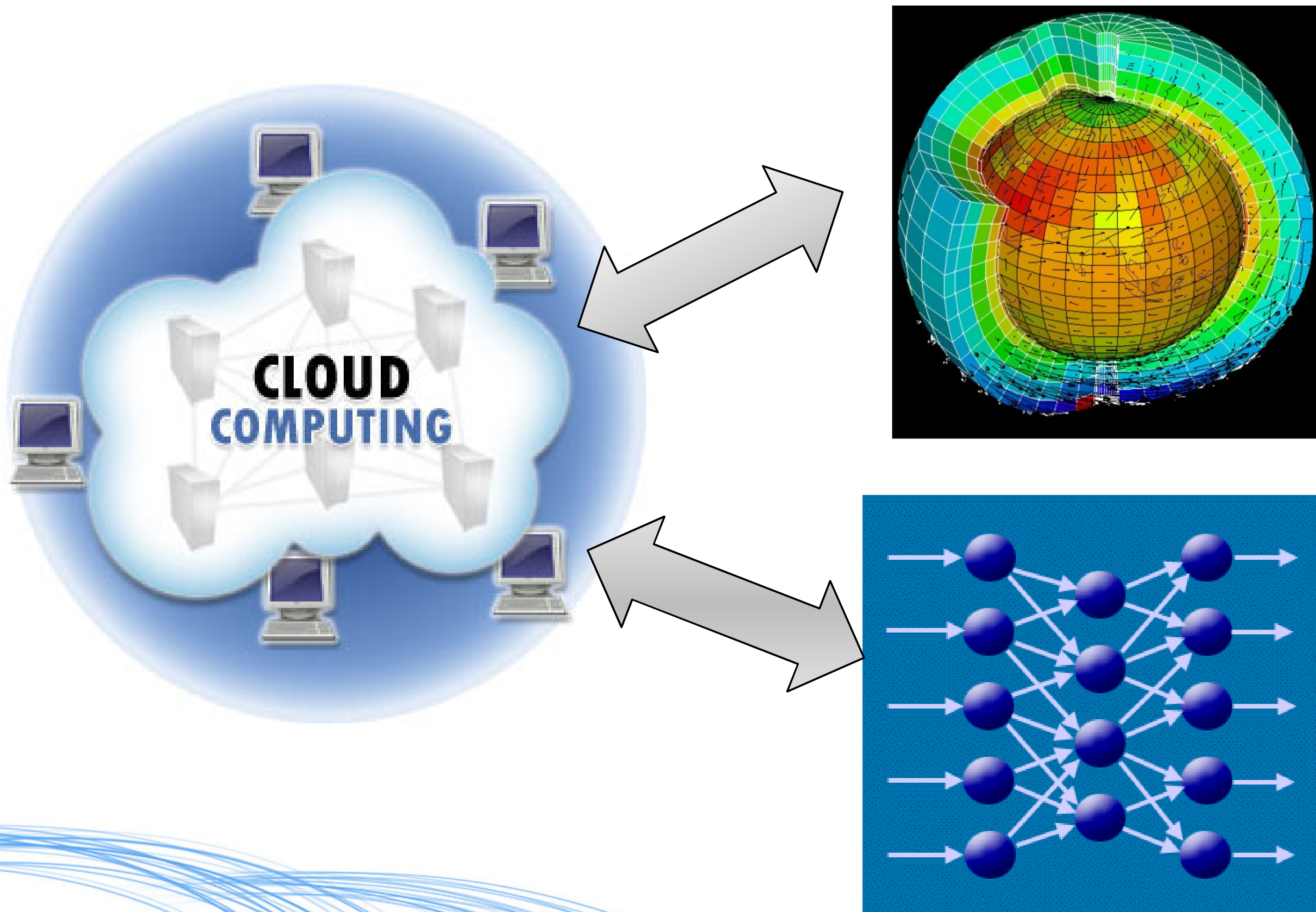
Solar Sensing Techniques: How do you deploy widely and process the data?

Total Sky Imagers

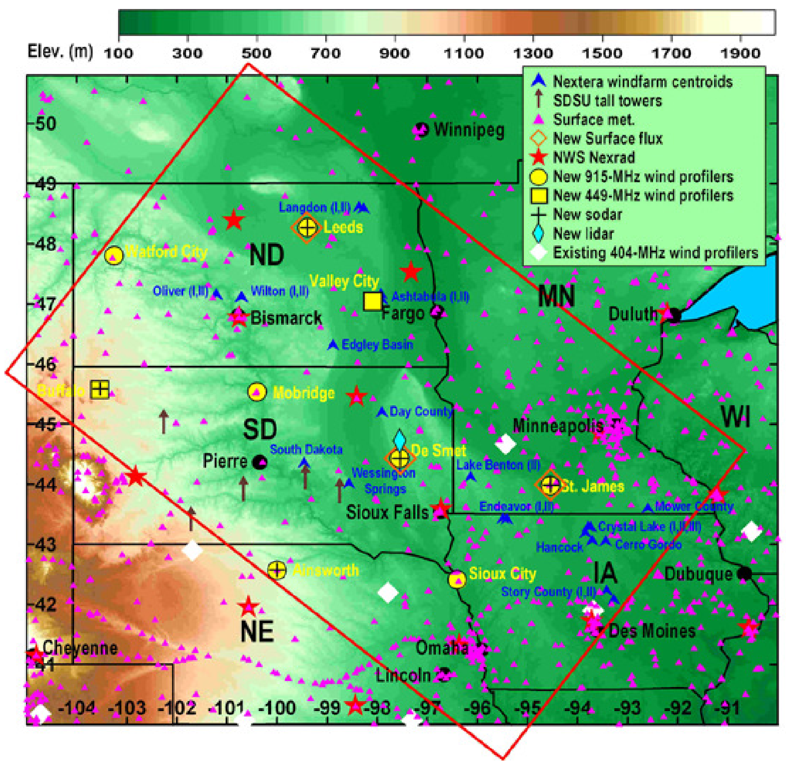
PV Cell = Fast Time Scale Irradiance Sensors

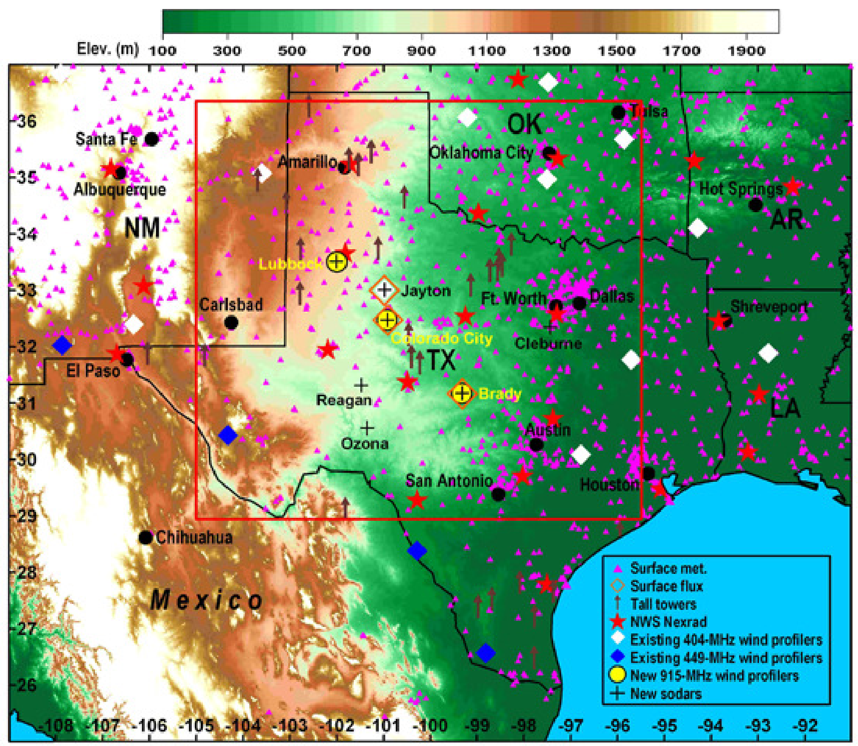
How do you log and communicate the data?

Software: Can we bring Cloud Computing Resources to Numerical Weather Prediction Models and Machine Learning?



How Can We Complement Existing DOE Projects such as the DOE/NOAA Wind Forecasting Improvement Project





arpa·e

Forecasting Program Name:

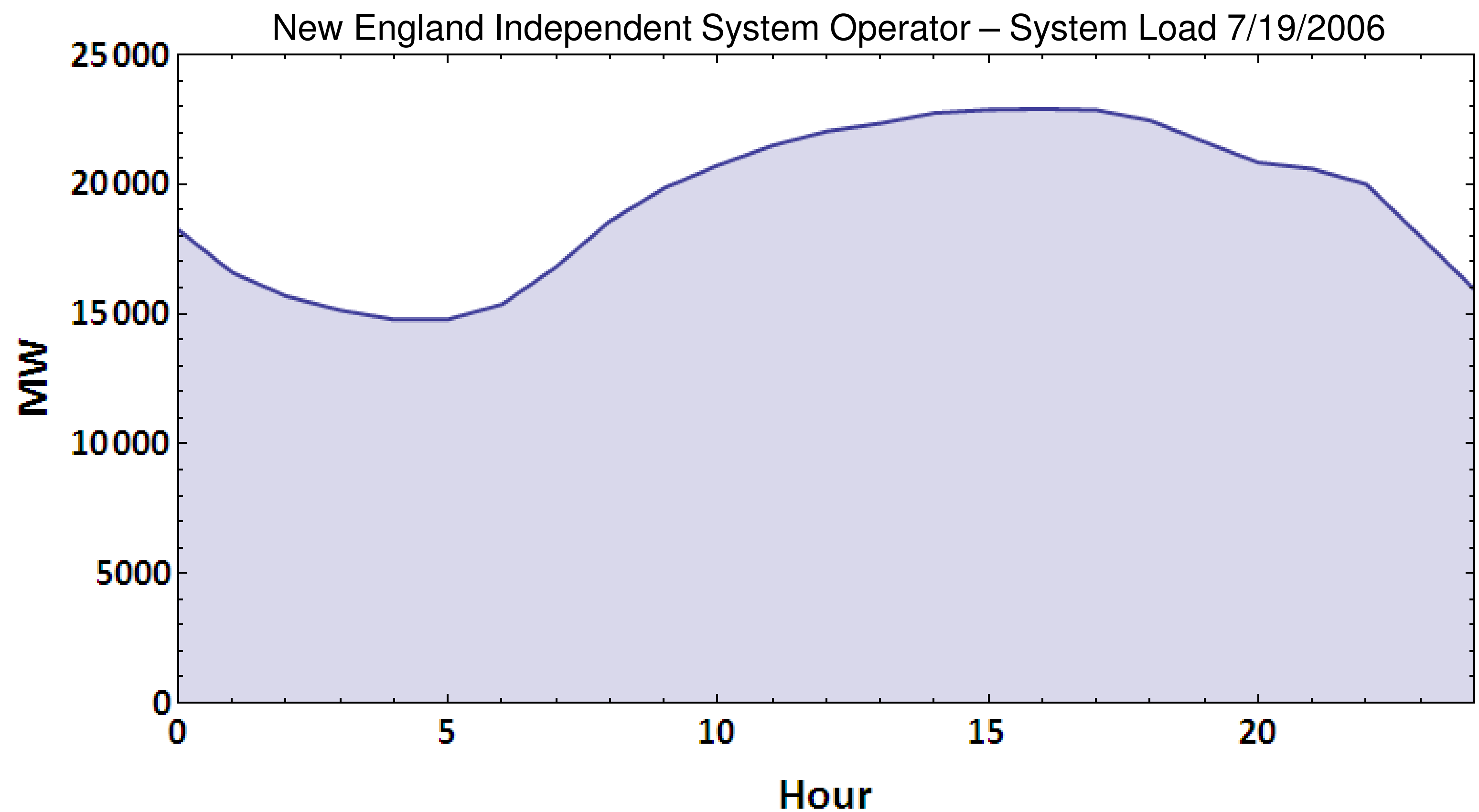
P REDICTING
R ENEWABLE
O PTIMUM
P RODUCTION OF
H EAT &
E LECTRICITY
T ECHNOLOGIES

Emerging Ideas

Real Time Electricity Pricing

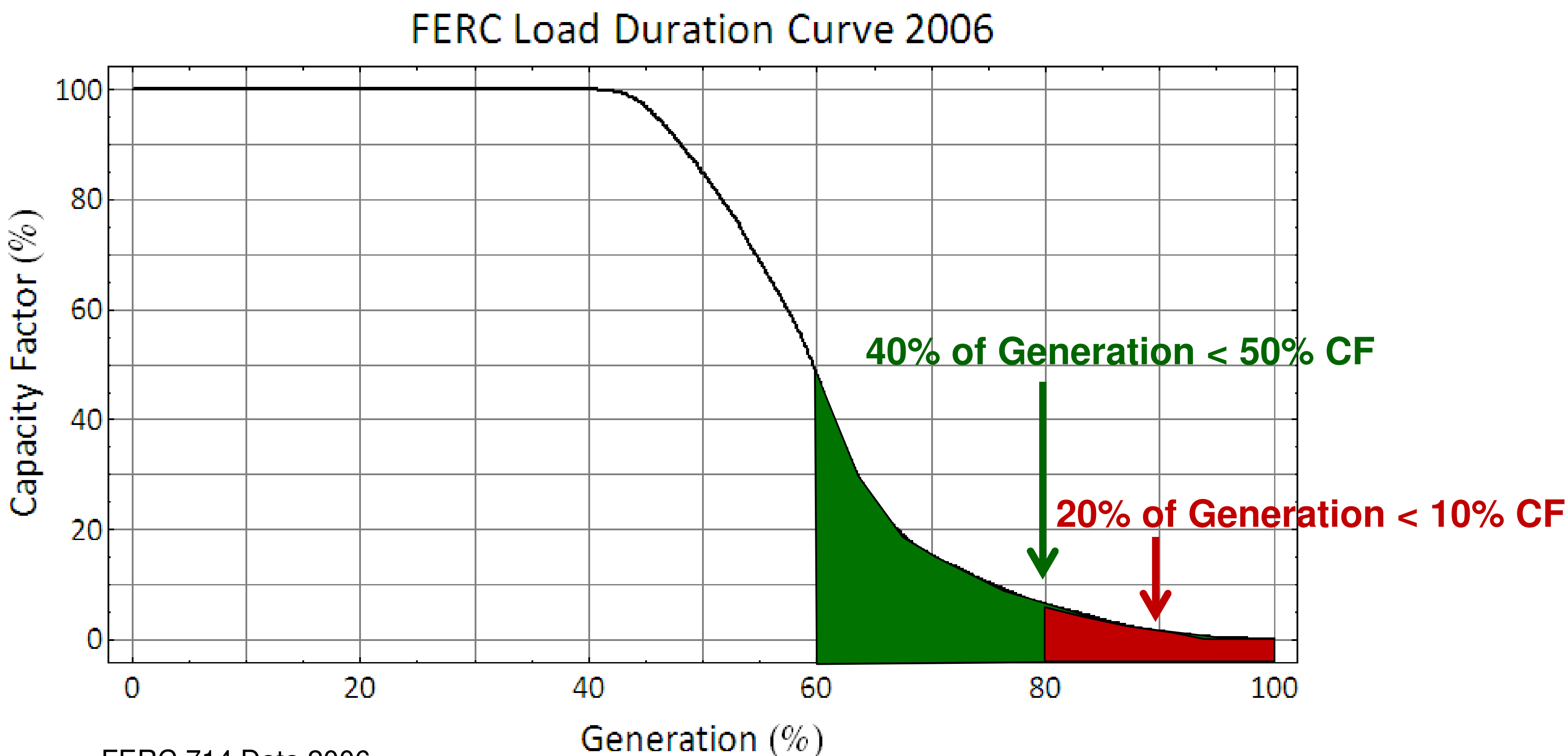
Timothy Heidel, ARPA-E Fellow

Demand for electricity varies



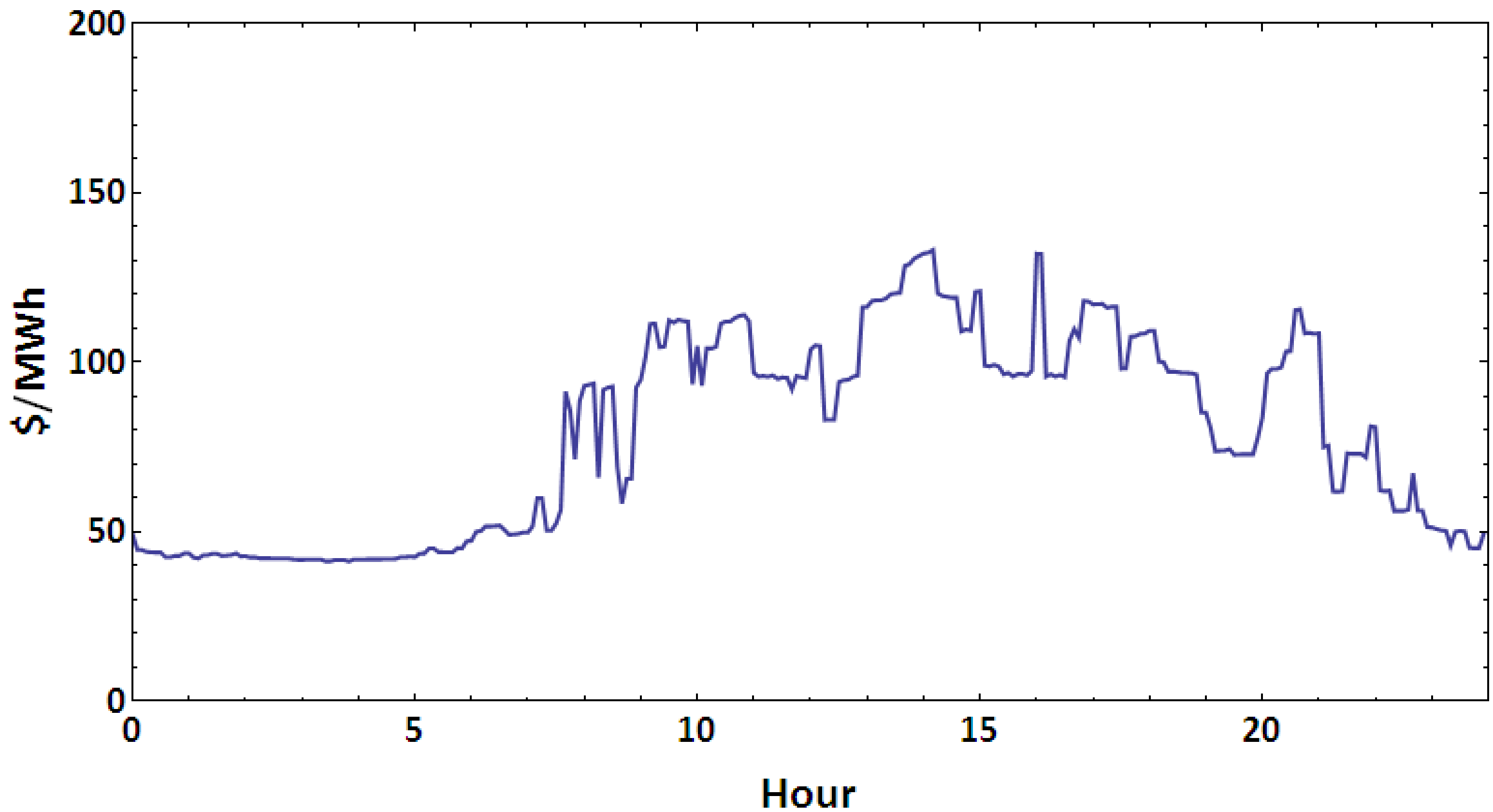
FERC 714 ISO-NE Data 2006/7/19

Varying demand yields low capacity utilization



FERC 714 Data 2006

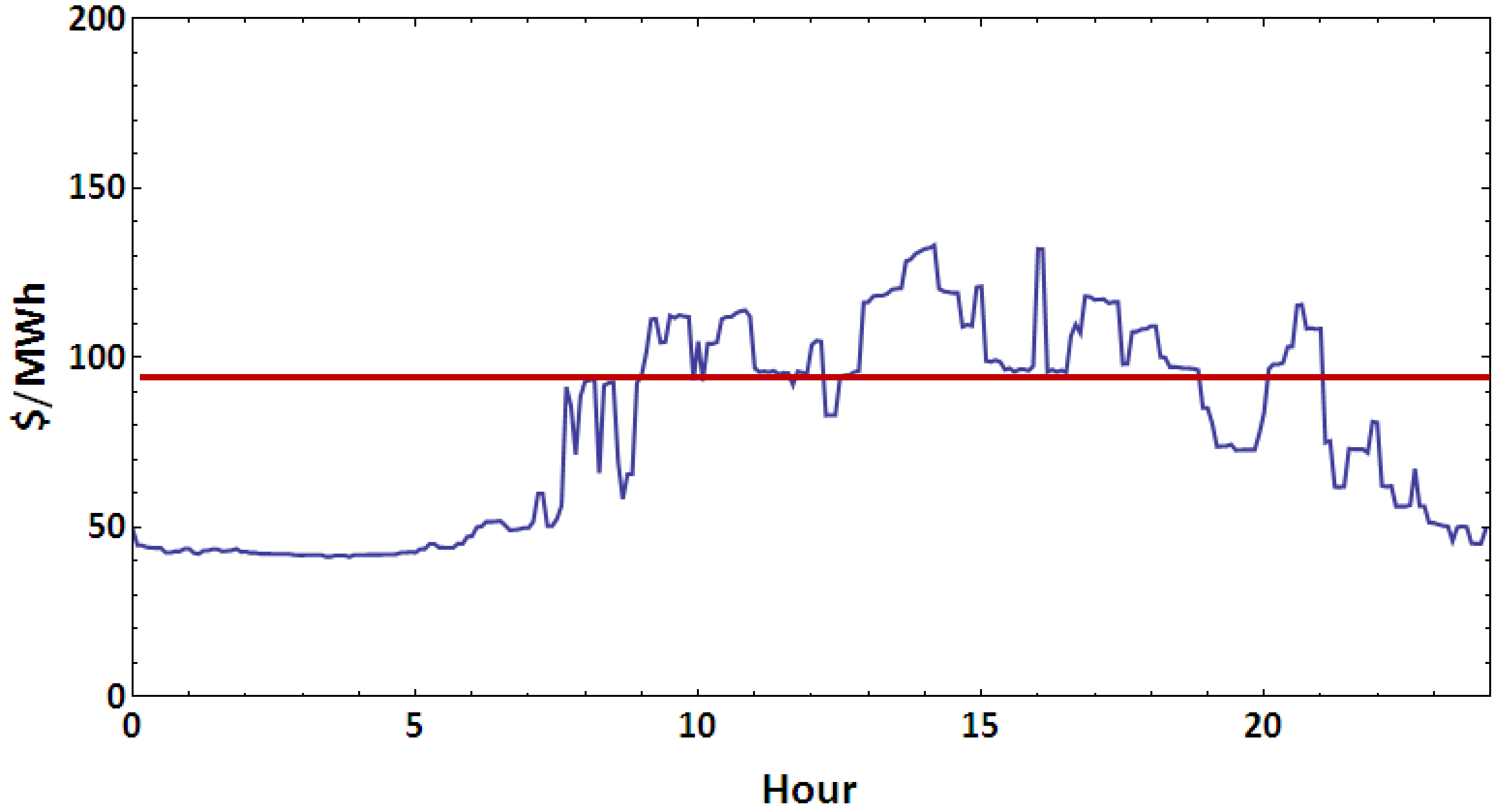
The cost of generation varies



ISO-NE Data 2011/7/19

The cost of generation varies

BUT, the price consumers pay is constant

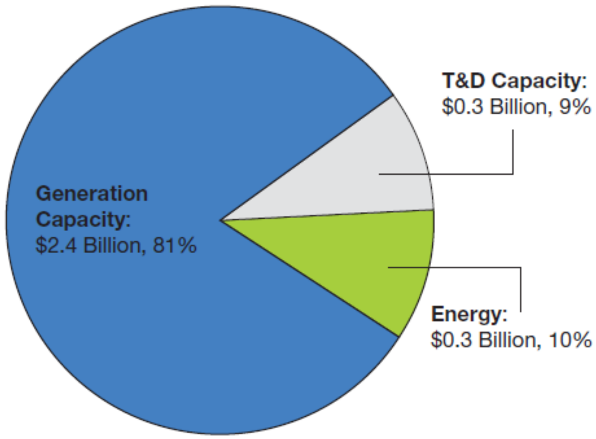


ISO-NE Data 2011/7/19, PEPCO Residential Rate 2012

Dynamic pricing could avoid the need for new capacity and reduce costs.

Annual Long-Run Savings
(National Estimate):
~ $ 3 Billion

Annual Short-Run Savings
(National Estimate):
~ $5-10 Billion



A. Faruqui, R. Hledik, S. Newell, J. Pfeifenberger, "The Power of Five Percent," The Brattle Group, May 2007.

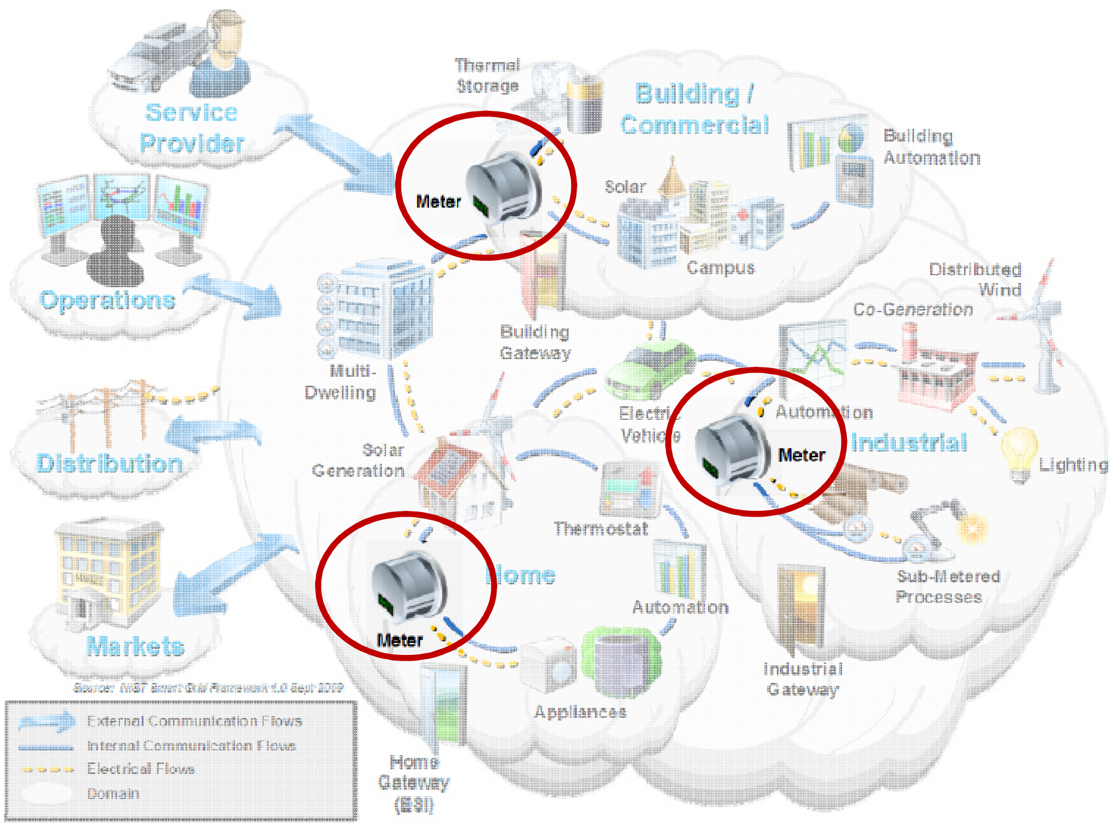
Dynamic pricing requires more granular measurements of electricity consumption.

- Smart meters are too expensive today: $150-$300 per meter (including meters, communications, back-office equipment, and installation).

Substantial cost reductions are needed

Existing approaches rely on a meter at every customer location

Smart Grid Customer Domain

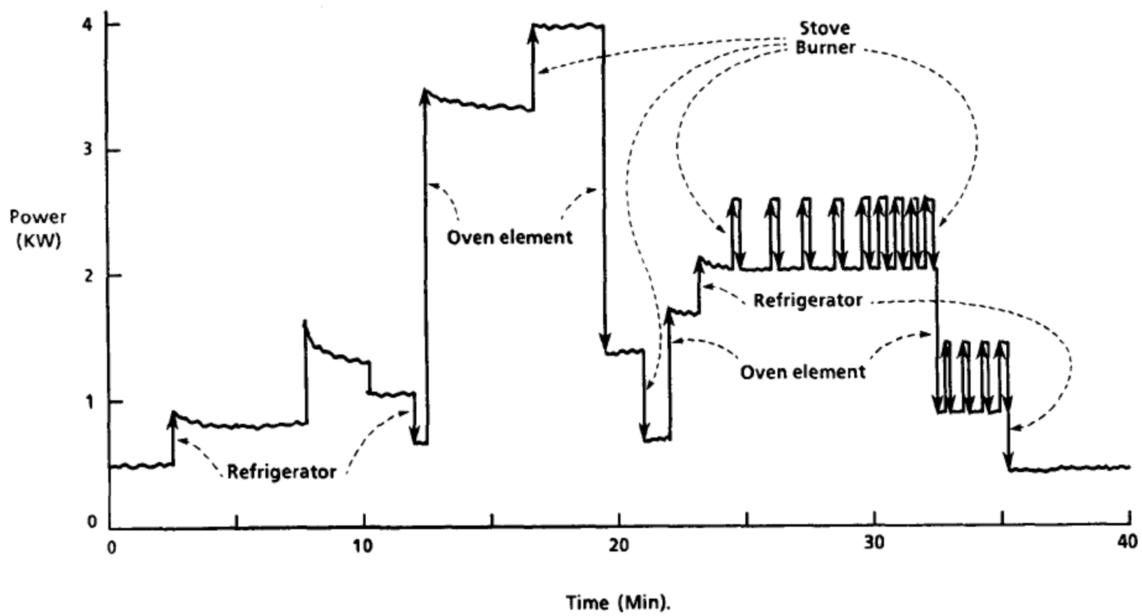


NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 1.0 (2010)

Approaches that do not require new meters?

- Individual appliances measure power consumption
  - Need cheap, secure, accurate integrated power measurement.
  - Devices communicate with utility via Internet automatically

- Substation Measurement
  - Nonintrusive load monitoring at the distribution feeder level.



Hart, "Nonintrusive Appliance Load Monitoring," IEEE (1992)

Potential Program Name:

P ROVIDING

R EAL TIME

I INTELLIGENT

C COSTS FOR

E LECTRICITY

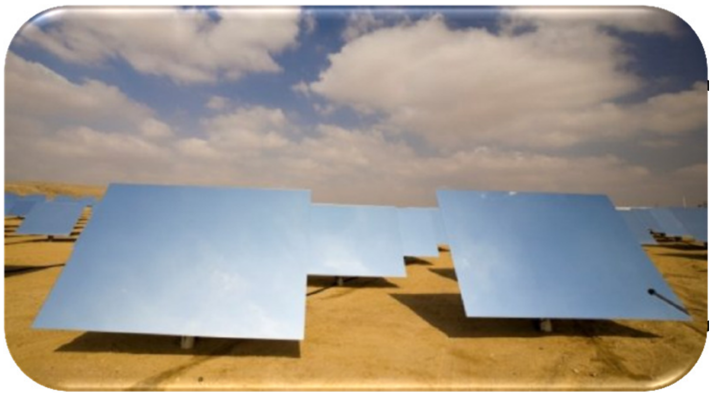
Emerging Ideas

Higher Efficiency Solar

Asegun Henry, ARPA-E Fellow

Collection

Conversion



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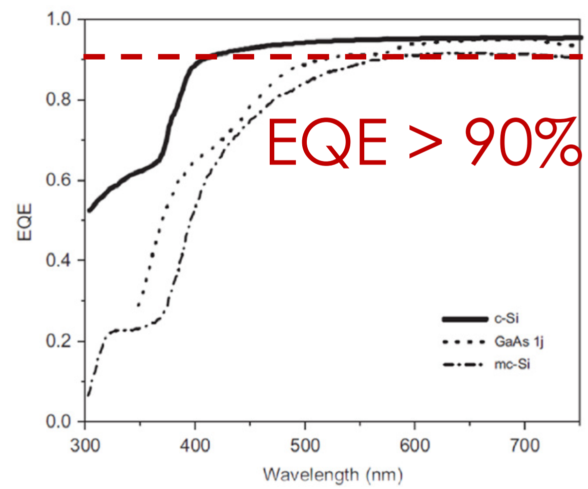
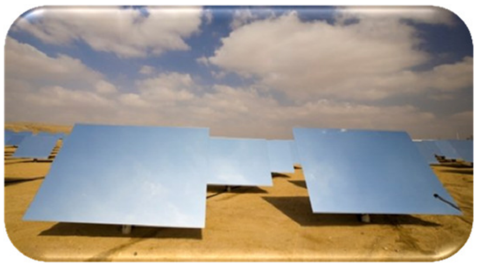
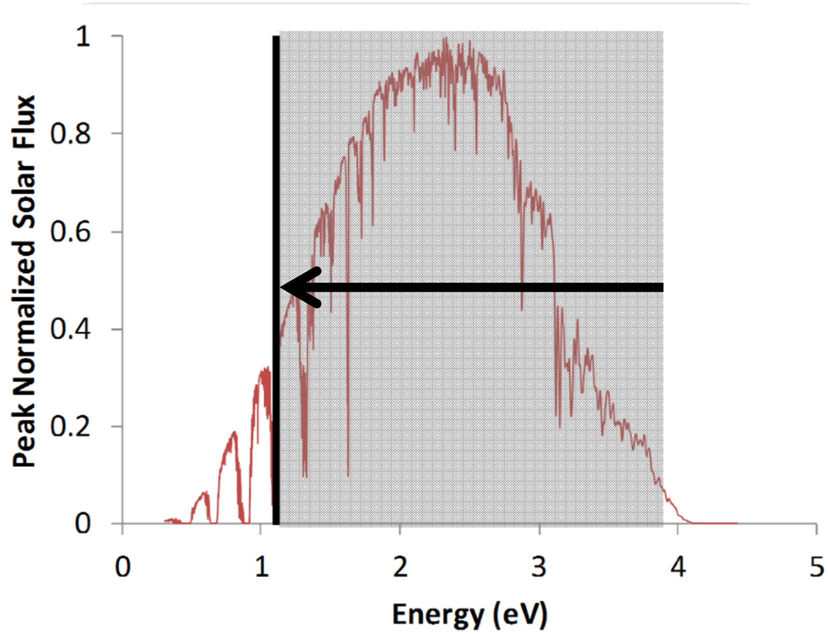


Cheap

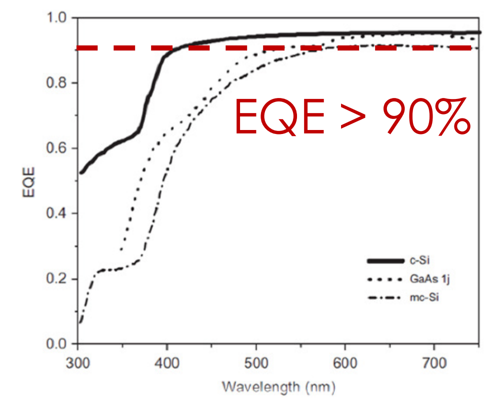
Efficient

Collection





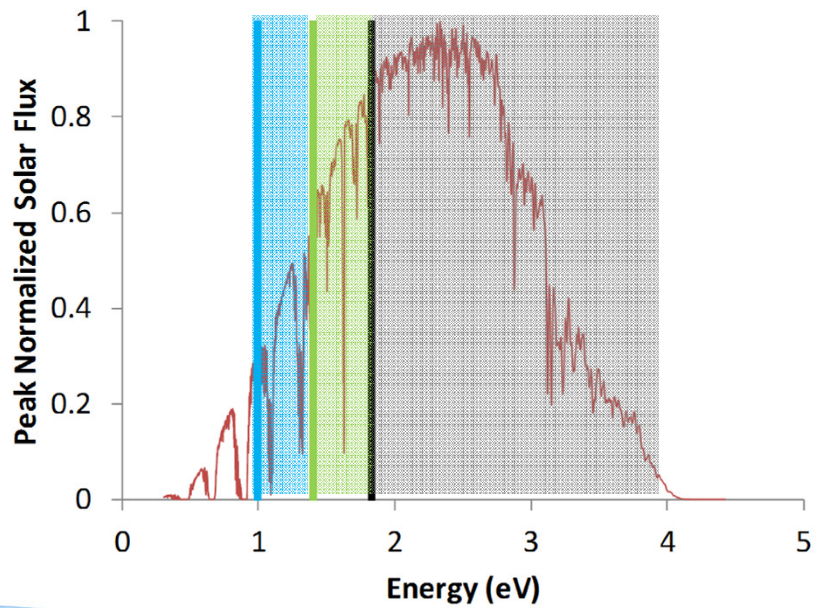
Conversion



Sacrifice
Efficiency

Collection

+



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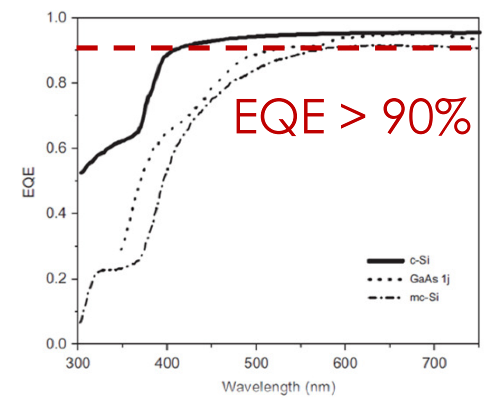
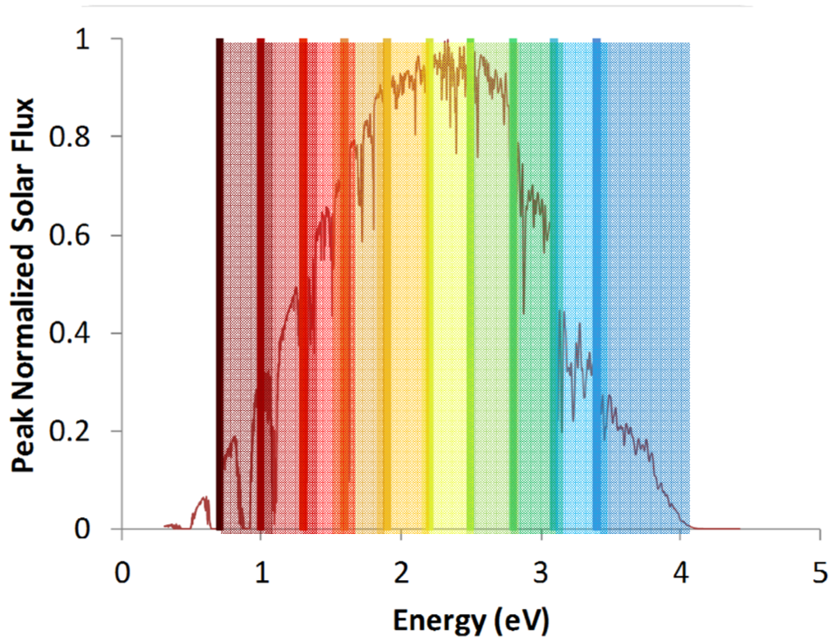


Collection



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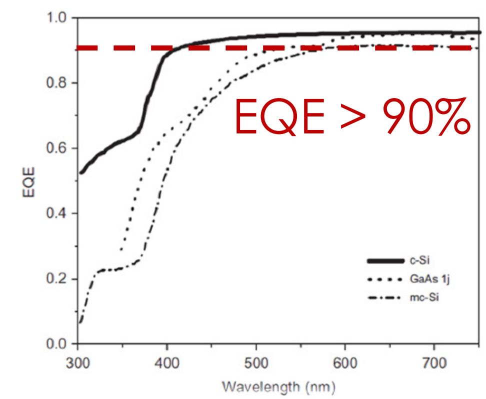
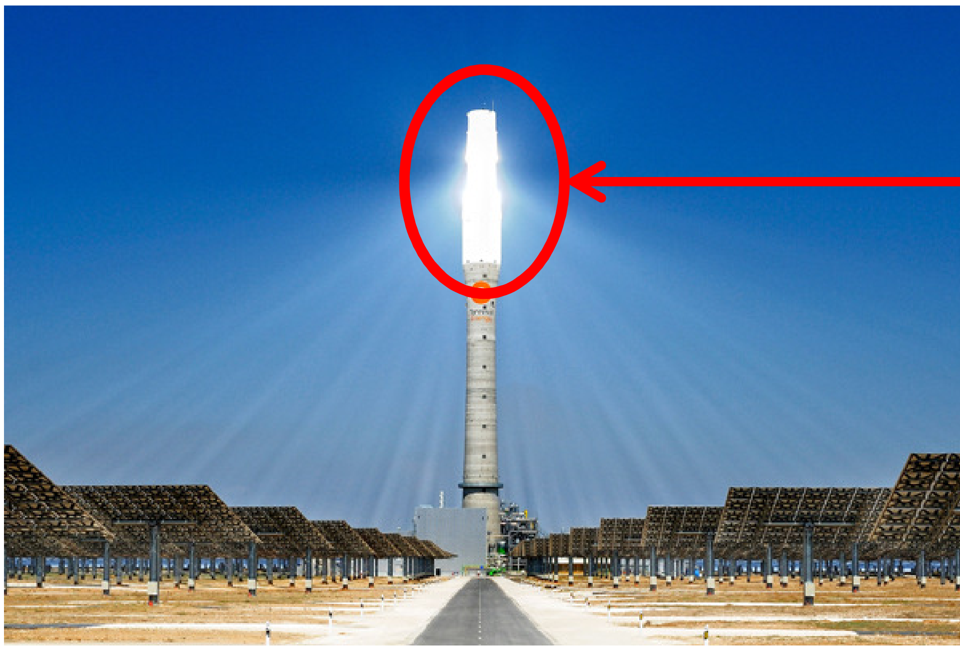
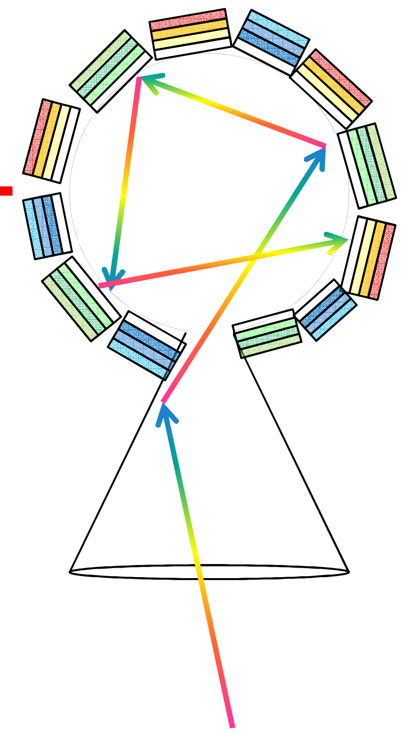


Optical System
Improves Efficiency

What about power tower CPV?

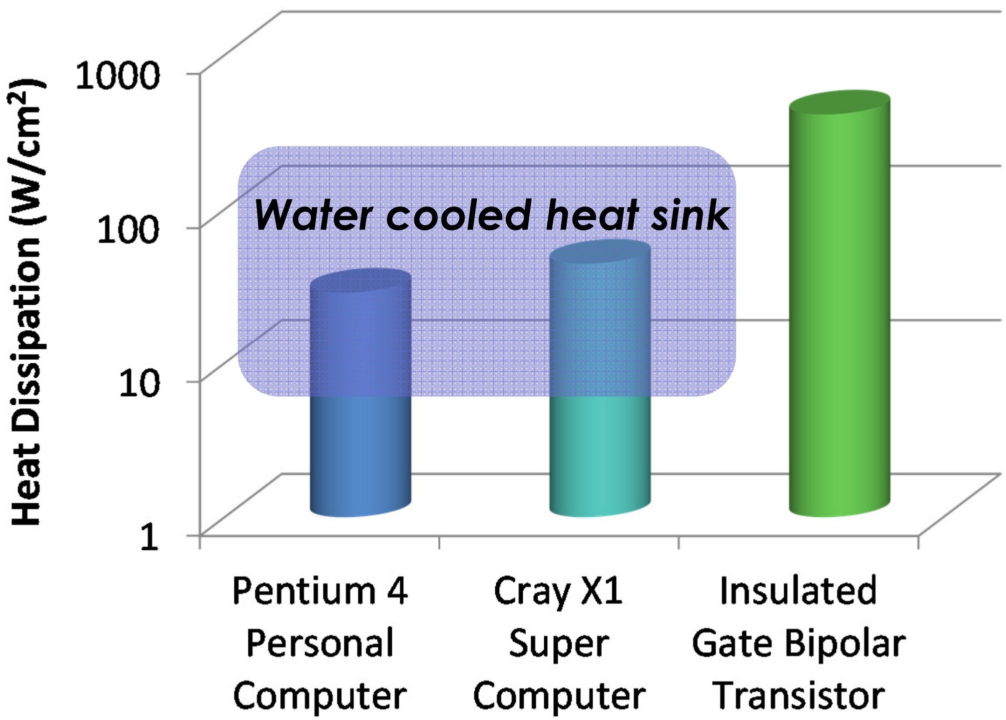


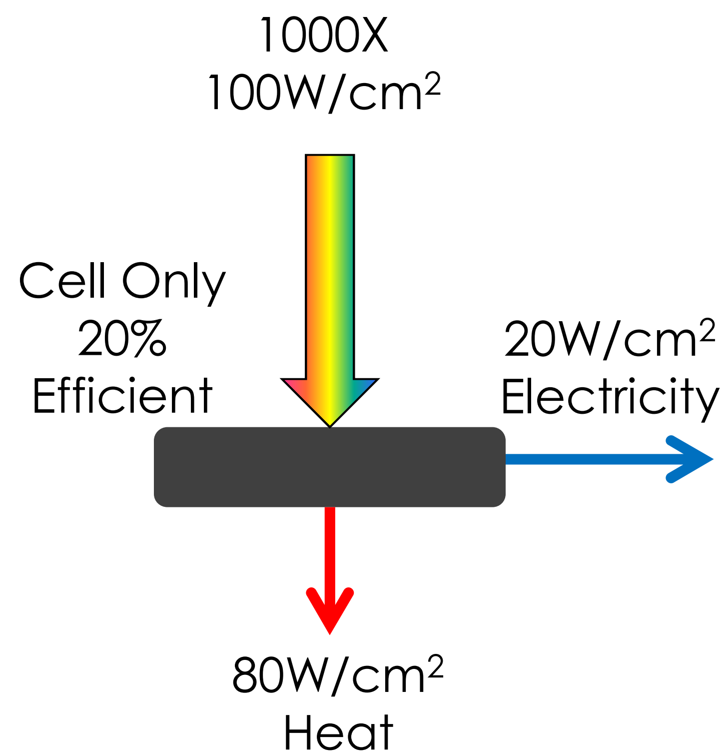
Multi-junction cells with band pass light filters



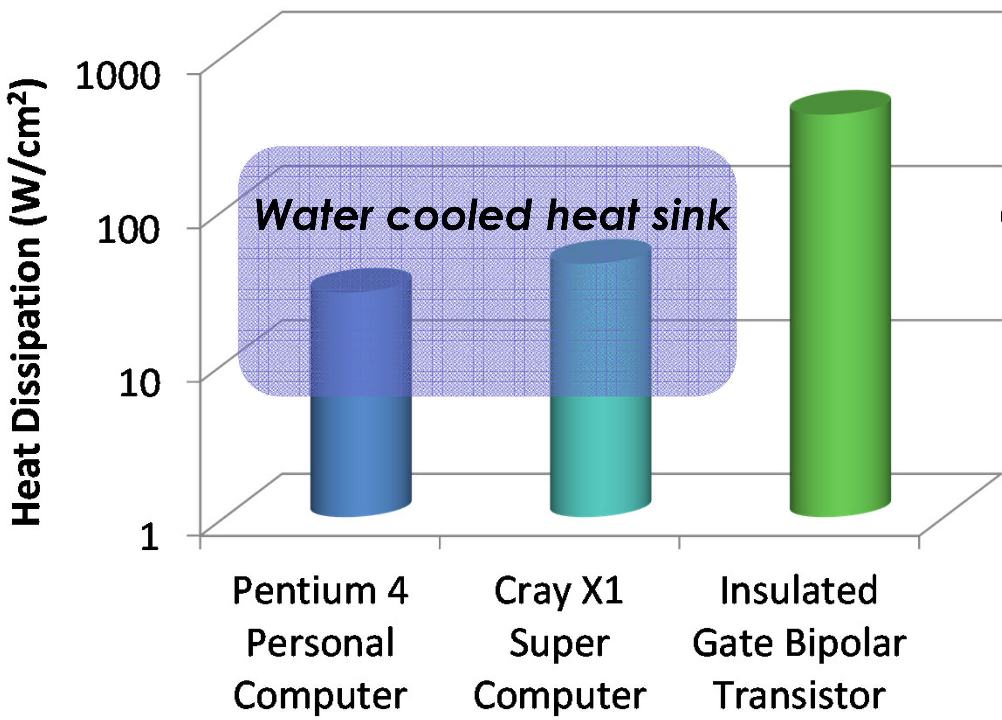
Goal: > 60% efficiency, < $1/Watt

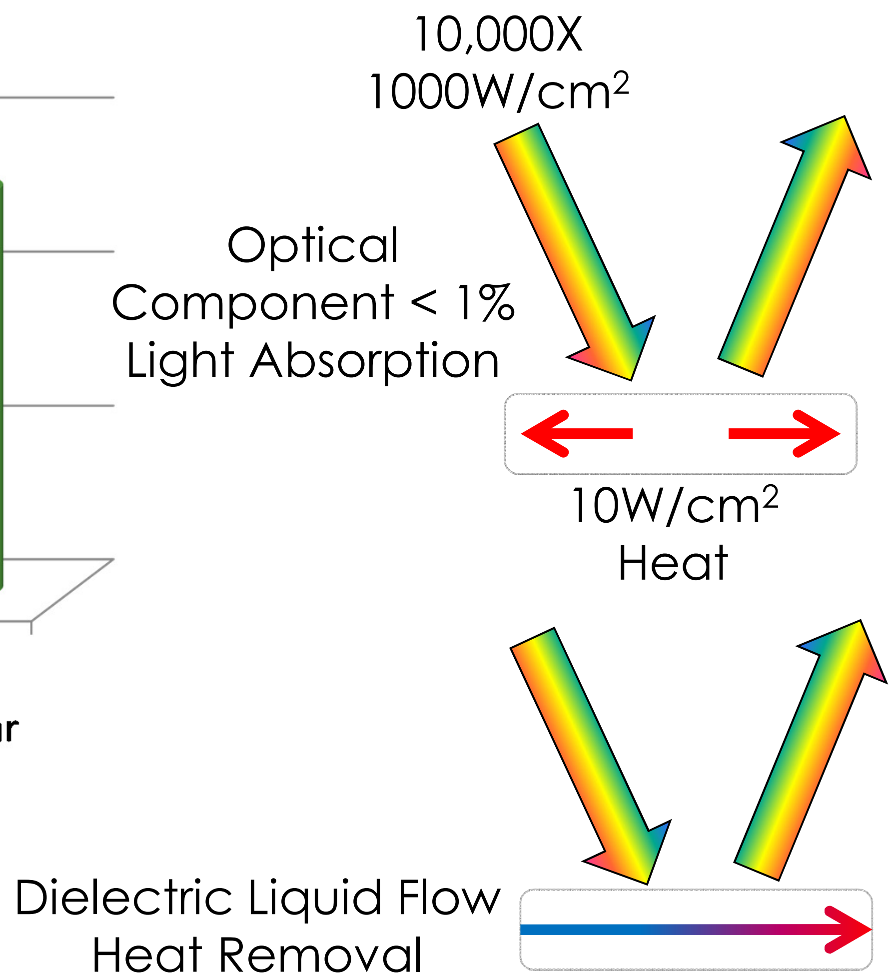
Can We Handle The Heat?





Can We Handle The Heat?



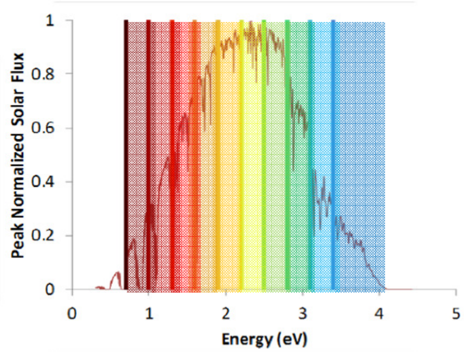


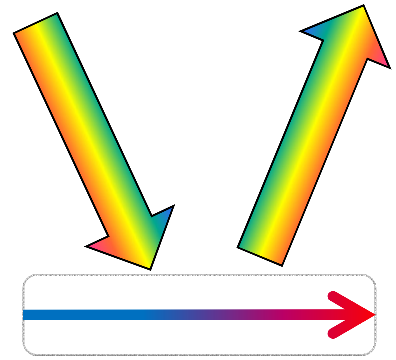
Collection

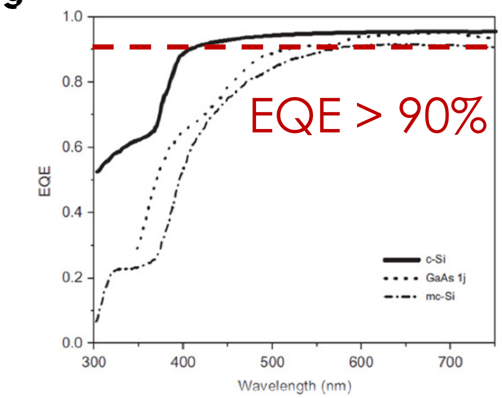
Spectral Splitting for Higher Efficiency

Optical Systems With Integrated Cooling

Conversion







Optical System
Improves Efficiency

Potential Program Name:

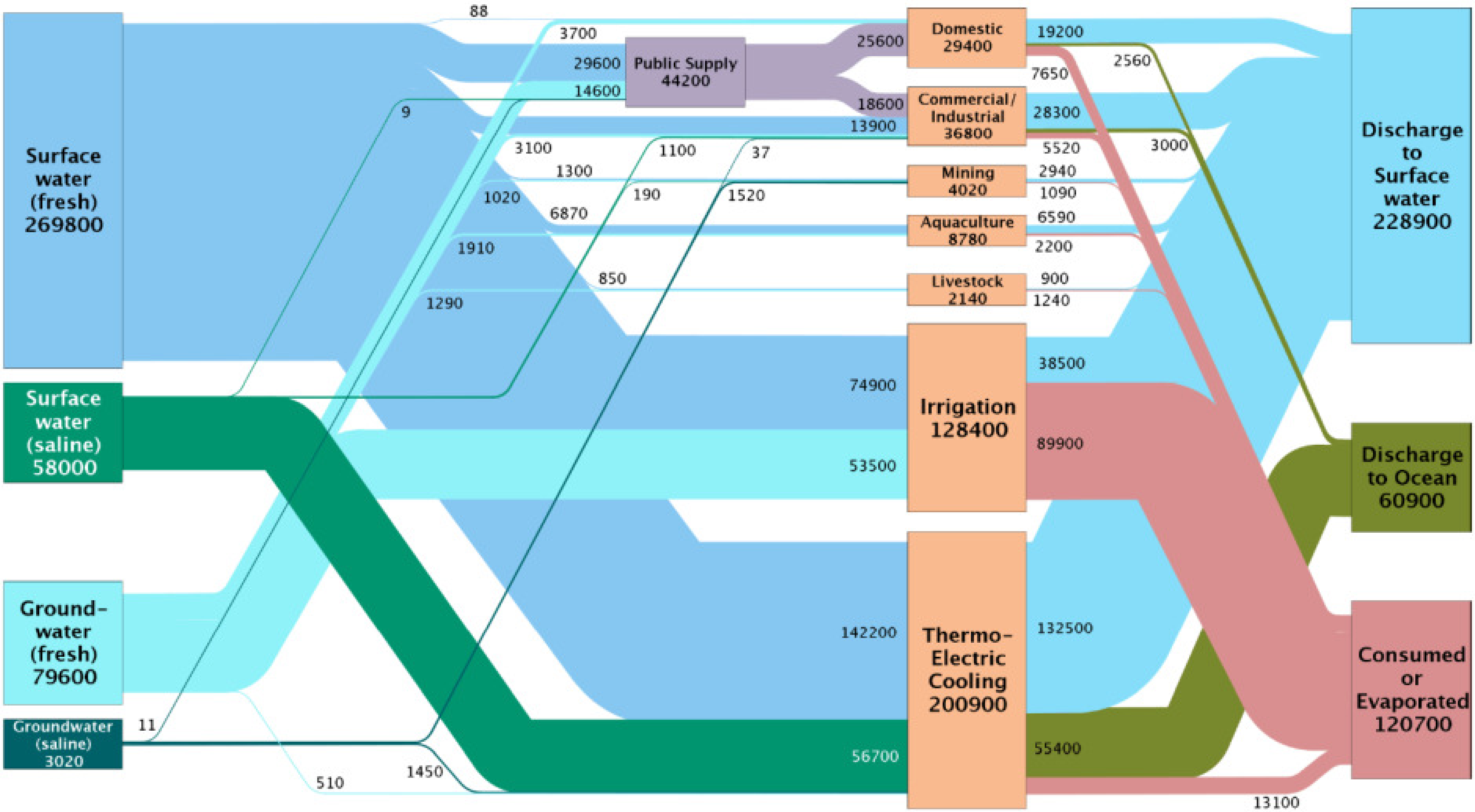
P HOTOVOLTAICS
H IGHLY
O PTIMIZED
T HROUGH
O PTICAL
N ETWORKS

Emerging Ideas

Low- or No-Water Power Plant Cooling

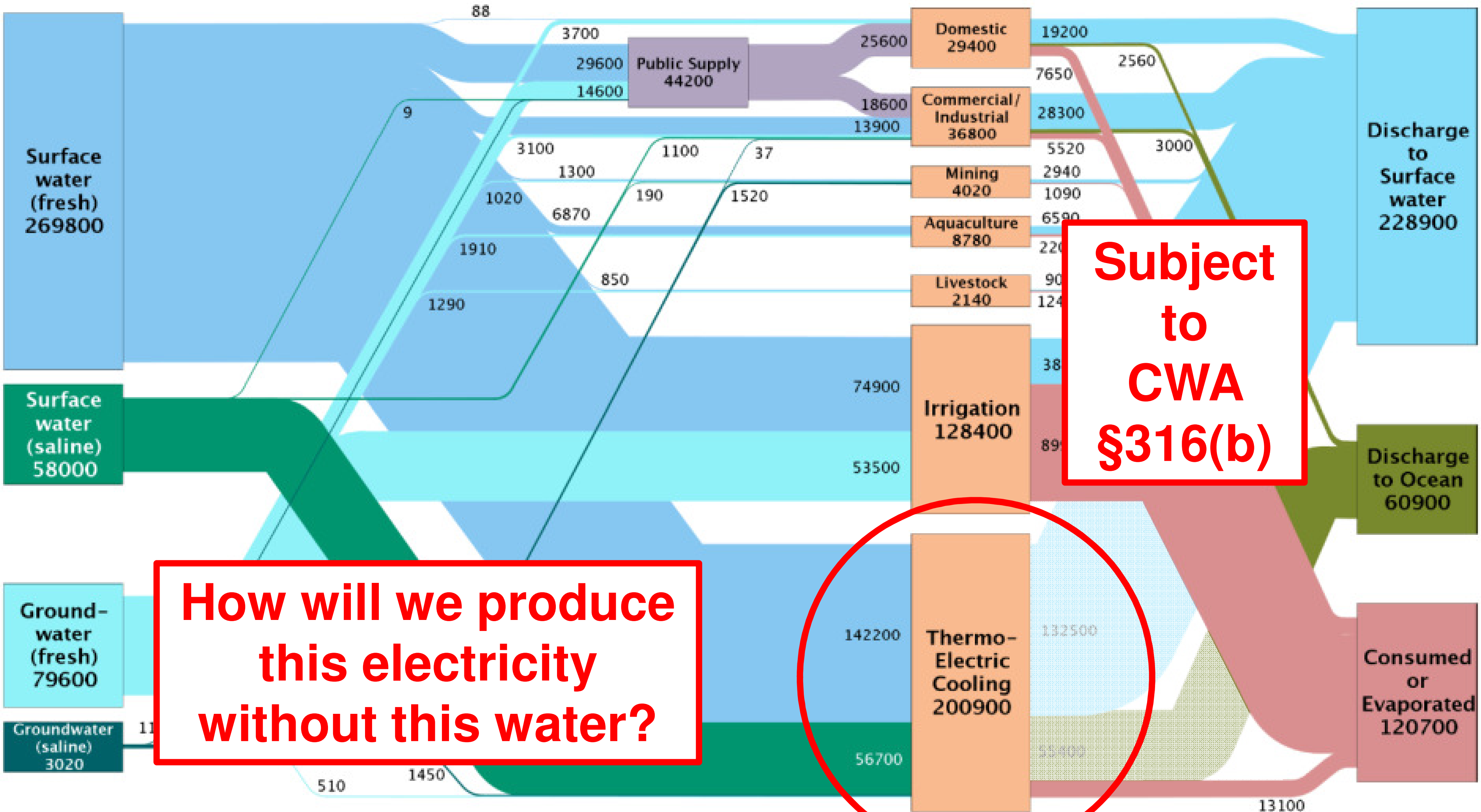
Nicholas Cizek, ARPA-E Fellow

Estimated US Water Flows 2005 (MGD), Total: 400 BGD



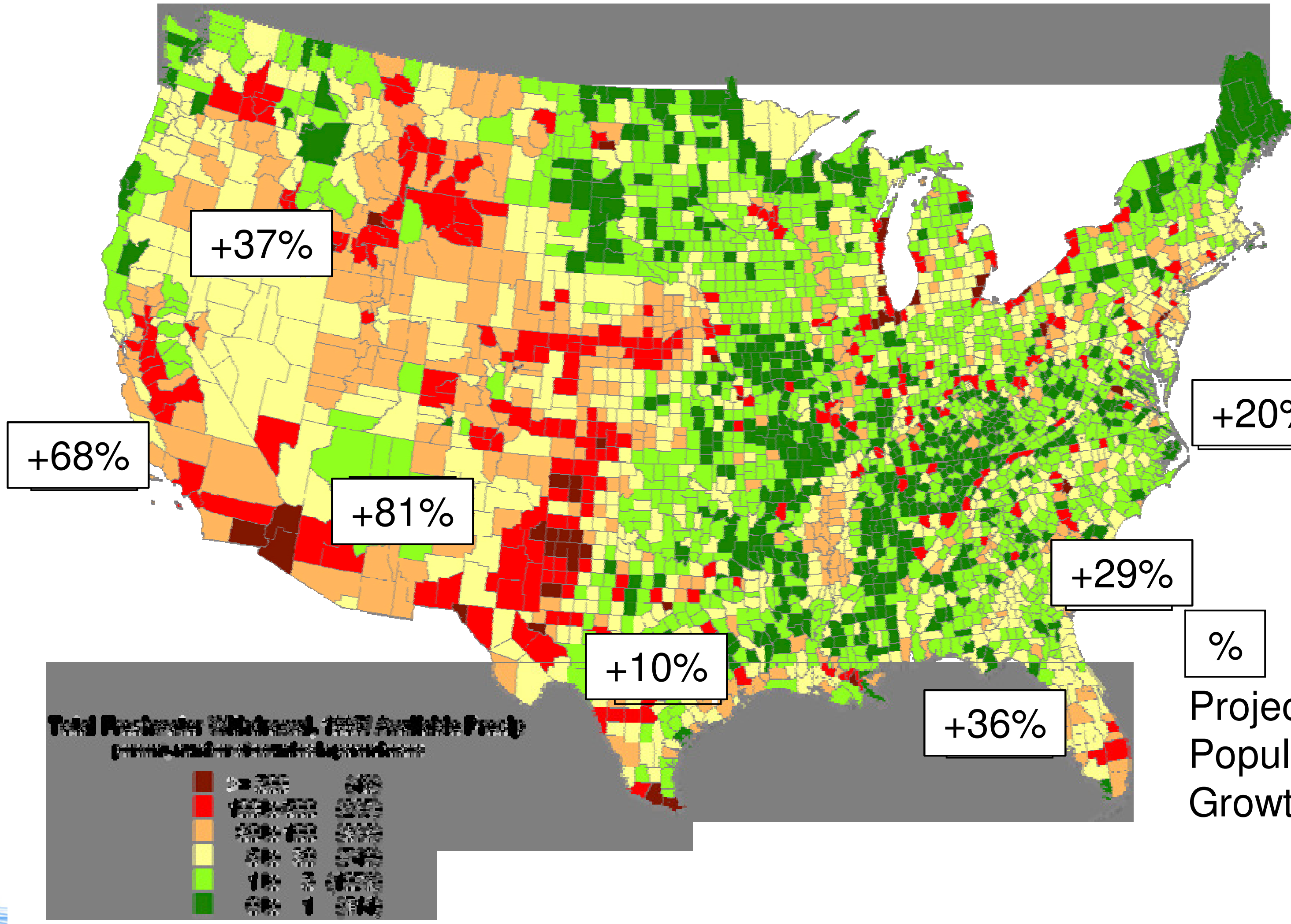
AJ Simons (LLNL and USDOE), 2010. Based on J Kenny (USGS), 2009

Estimated US Water Flows 2005 (MGD), Total: 400 BGD



AJ Simons (LLNL and USDOE), 2010. Based on J Kenny (USGS), 2009

30% Population Increase by 2030, Mostly DRY PLACES



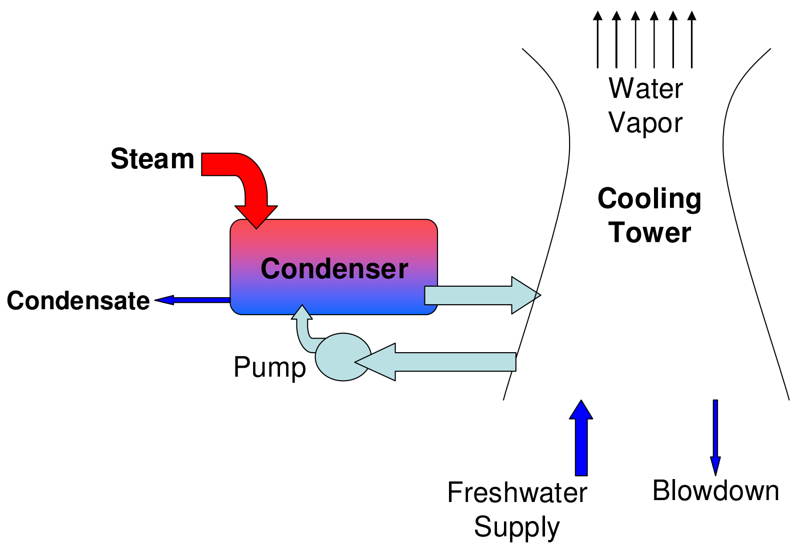
%
Projected
Population
Growth

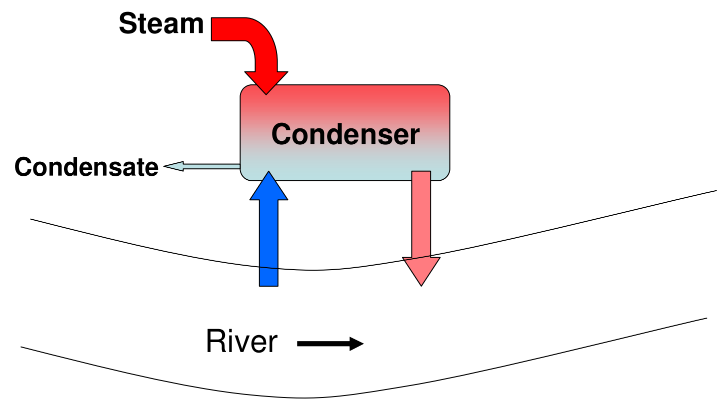
Solley (USGS), 1998; EPRI, 2003; Campbell (US DOC), 1997

Traditional Power Plant Cooling

“Open Loop” / “Once-Through” Cooling

“Closed Loop” Cooling





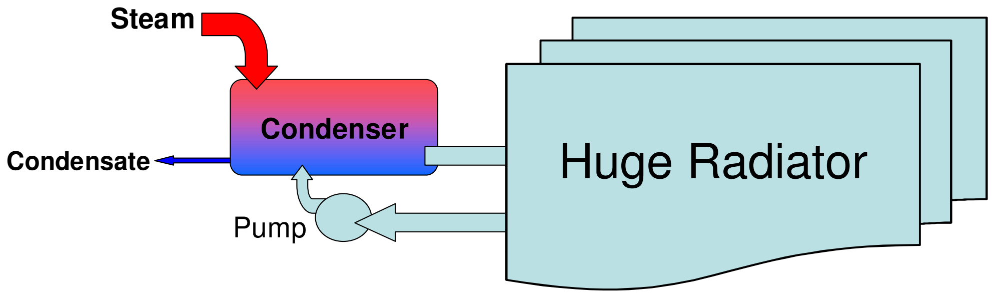
Q Evaporates H_2O

Q Raises River Temp
- Raises Air Temp
- Evaporates H_2O

Problem Statement

Dissipate GW-scale low-grade heat (95 F) into air without evaporating water

Air Cooled Power Plant



Q Raises Air Temp Only

But $T_c = T_{air}$ instead of $T_{water} = T_{air,ave}$

6-16% Less Electricity

Are there low-/no-water cooling tech pathways to achieve $T_c = T_{air,ave}$ instead of $T_c = T_{air}$?

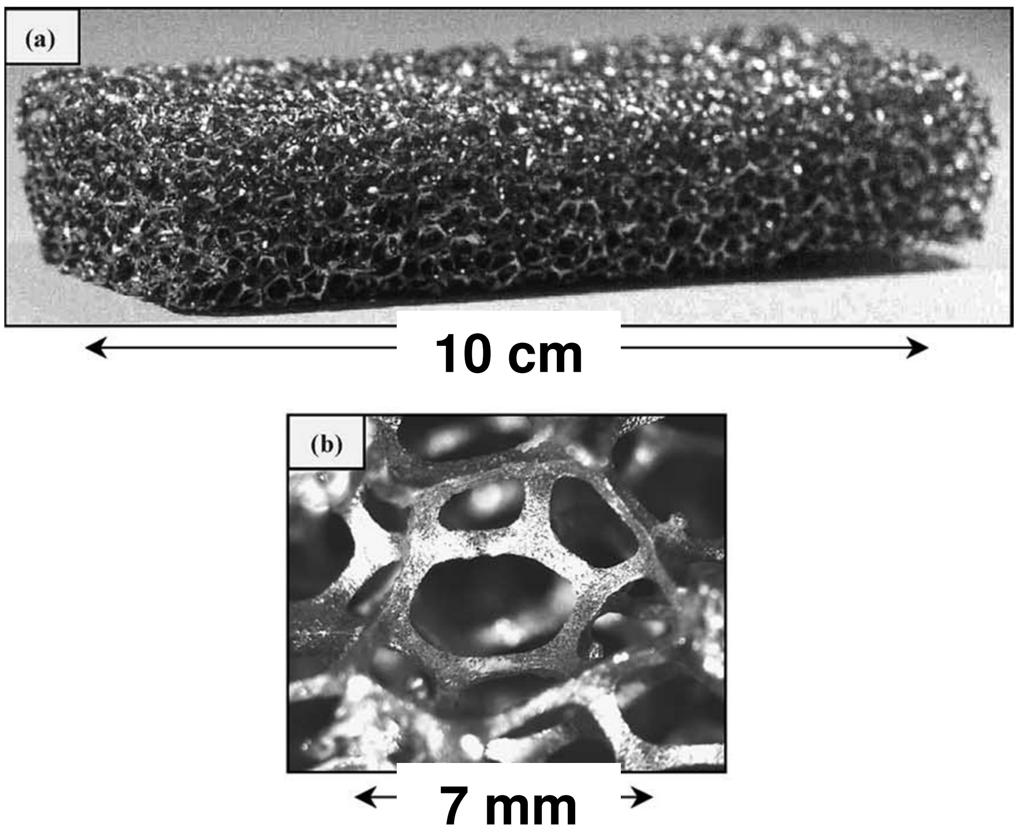
Thermal Battery (low vapor pressure)

- Dirt
- Liquid besides water

Otherwise efficiency loss unavoidable

Low-/No-Water Cooling Tech Paths To Wet Cooling LCOE

Increase Surface Area – thermally conducting polymer, metal foam



Boomsma, *et al*, Mechanics of Materials, 2003

Low-/No-Water Cooling Tech Paths To Wet Cooling LCOE

Increase Air Speed – elevate condenser

Wind ~10 m/s at 100 m

Low-/No-Water Cooling Tech Paths To Wet Cooling LCOE

Increase Thermal Conduction Coefficient – coatings, nanostructures

Non-Rankine bottoming cycle – parallel Stirling

Low-/No-Water Power Plant Cooling Techno-Economic Goal

Dry Cooled Power Plant LCOE

< 5¢/kWh

Low-/No-Water Power Plant Cooling Name

I MPROVING

C OOLING

E FFICIENCY of

P O WER

P LANTS